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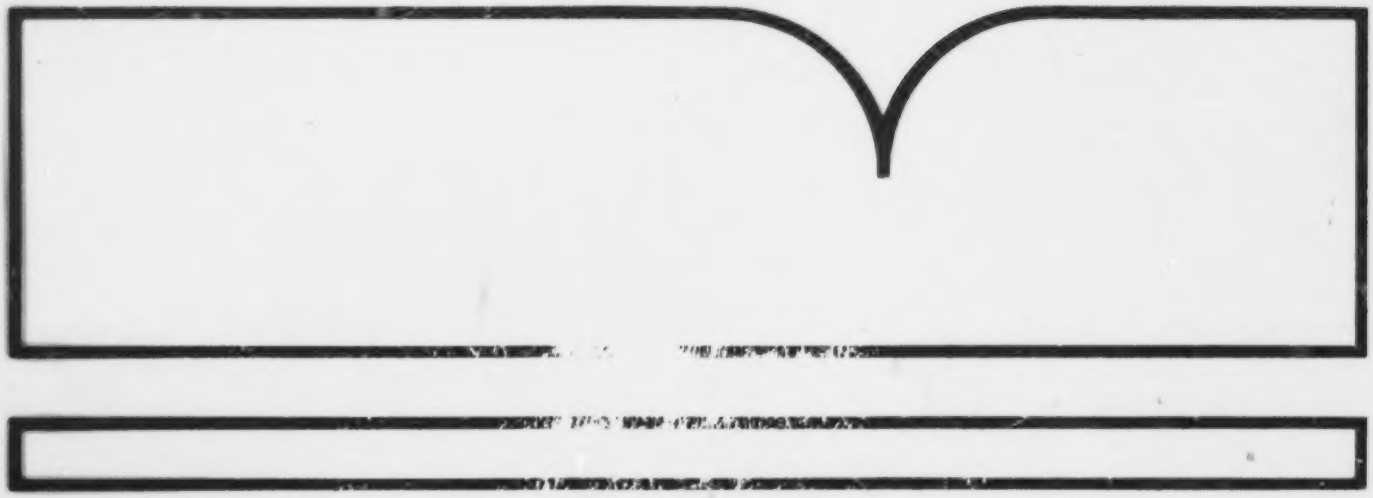

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16. ABSTRACT

Flow-through and static tests were conducted with fathead minnows, rainbow trout and Daphnia magna to determine their relative sensitivities to measured concentrations of the insecticide endosulfan and to compare responses of fish in replicated static and flow-through exposure procedures. Fathead minnow 96-h static LC_{50} values were 1.3, 0.8 and 1.3 µg/L endosulfan. The 96-h LC_{50} values for fatheads in flow-through tests were 1.7 and 1.0 µg/L. Rainbow trout 96-h LC_{50} values were 1.7 and 1.6 µg/L. The 96-h LC_{50} values for rainbows in flow-through tests were 0.3 and 0.4 µg/L. Acute 48-h static EC_{50} values for D. magna were 343 and 271 µg/L endosulfan. These results suggest that differences in species sensitivity can be as great as three orders of magnitude.

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Short Communication

RELATIVE SENSITIVITY OF *DAPHNIA MAGNA*, RAINBOW TROUT AND FATHEAD MINNOWS TO ENDOSULFAN

*ALAN V. NEBEKER, JOEL K. MCCRADY, ROGER MSHAR and CHRIS K. MCAULIFFE

U.S. Environmental Protection Agency
Corvallis Environmental Research Laboratory
200 S.W. 35th Street
Corvallis, Oregon 97333

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Abstract — Flow-through and static tests were conducted with fathead minnows, rainbow trout and *Daphnia magna* to determine their relative sensitivities to measured concentrations of the insecticide endosulfan and to compare responses of fish in replicated static and flow-through exposure procedures. Fathead minnow 96-h static LC_{50} values were 1.3, 0.8 and 1.3 μg/L endosulfan. The 96-h LC_{50} values for fatheads in flow-through tests were 1.7 and 1.0 μg/L. Rainbow trout 96-h static LC_{50} values were 1.7 and 1.6 μg/L. The 96-h LC_{50} values for rainbows in flow-through tests were 0.3 and 0.4 μg/L. Acute 48-h static EC_{50} values for *D. magna* were 343 and 271 μg/L endosulfan. These results suggest that differences in species sensitivity can be as great as three orders of magnitude.

Keywords — Endosulfan Fathead minnow Rainbow trout *Daphnia magna* Acute toxicity

INTRODUCTION

This paper presents information on the comparative sensitivities of three freshwater animals, the rainbow trout *Salmo gairdneri*, the fathead minnow *Pimephales promelas* and the crustacean *Daphnia magna*, to measured concentrations of the insecticide endosulfan. Static and flow-through 96-h tests were conducted with fish to compare the resulting 96-h LC_{50} values for each type of test procedure. Endosulfan LC_{50} values (lethal concentration causing 50% death of animals after 96 h) are available for aquatic life, but are difficult to compare because of differences in water quality, species used, measured versus unmeasured concentrations, type of test, etc. Schoettger [1] reported static unmeasured 96-h LC_{50} values of 0.3 and 0.8 μg/L for rainbow trout, whereas Macek et al. [2] reported static unmeasured test LC_{50} values of 1.5 to 2.6 μg/L. Acute LC_{50} values for *D. magna* in static unmeasured tests ranged from 62 [1] to 166 μg/L [3]. Sanders [4] reported a static unmeasured LC_{50} value of 5.8 μg/L for *Gammarus lacustris*. Macek et al. [3] reported a chronic effect value of 0.28 μg/L for the fathead minnow and a chronic value of 4.3 μg/L for *D. magna*.

METHODS AND MATERIALS

Fathead minnows were hatched and reared from cultures obtained from the

*To whom correspondence may be addressed at: 1350 S.E. Goodnight Avenue, Corvallis, OR 97333.

Western Fish Toxicology Station (WFTS), Corvallis, Oregon. The original fish were collected in 1978 from Oregon State Fish and Wildlife Department ponds near Aumsville, Oregon. The rainbow trout were obtained as eggs from the Oregon State Fish and Wildlife Department Oak Ridge Hatchery and were hatched and reared at WFTS. Fish were not fed during testing. *D. magna* were reared from cultures at WFTS; original cultures were obtained in 1971 from the National Water Quality Laboratory (Environmental Protection Agency; EPA), Duluth, Minnesota. *Daphnia* were fed blended trout chow and yeast in cultures but were not fed during the acute tests.

Unchlorinated water used for testing was obtained from wells and was aerated vigorously before use. Water temperature and hardness during acute testing are listed in Table 1. Hardness values were obtained using standard methods [5].

The methods used for the acute tests with *Daphnia*, rainbow trout and fathead minnows were basically those presented in the "Standard Practice for Conducting Acute Toxicity Tests with Fishes, Macroinvertebrates, and Amphibians" [6]. Five test concentrations plus a control, and a solvent control when necessary, were used for all tests, with a 50% dilution ratio between concentrations. *Daphnia* were tested in 200 ml of water contained in 250-ml beakers. Five daphnids < 24 h old were placed in each beaker, with four beakers at each concentration. Static fish tests were conducted using aerated 20-liter jars. Ten fish were placed in each jar, with two jars per concentration. Flow-through fish tests were conducted in 20-liter aquaria using a Garton diluter water delivery system [7]. Ten fish were placed in each aquarium, with two aquaria per concentration.

The insecticide endosulfan ($C_9H_6Cl_6O_3S$) was used for testing. The technical-grade endosulfan that was used is a mixture of two isomers that differ in their chemical, physical and toxicological properties. Endosulfan I, which makes up approximately 70% of the endosulfan, is more toxic than Endosulfan II [8]. Endosulfan sulfate, the principal degradation product which is almost as toxic as endosulfan, was not measured. Both isomers were measured after hexane extraction by gas chromatography and ^{63}Ni electron capture detection. Endosulfan LC_{50} values were calculated using the summation of both isomers in the regression methods. The ratio of the two isomers remained relatively constant at the expected 7:3 ratio

Table 1. Acute endosulfan toxicity to *Daphnia magna*, rainbow trout and fathead minnow

Species	Test type[a]	96-h LC_{50}[b] (μg/L)	Confidence limits (95%)	Mean fish fork length (mm)	Mean fish wt. (g)	Mean temp. (°C)	Mean water hardness (mg/L)
Daphnia	Static	343[c]	263–447	—	—	20	35
Daphnia	Static	271[c]	226–325	—	—	20	33
Rainbow	Static	1.7	0.8–3.7	46	1.3	12	34
Rainbow	Static	1.6	1.4–1.9	46	1.3	12	30
Rainbow	Flow-through	0.3	0.3–0.4	40	0.6	12	27
Rainbow	Flow-through	0.4	0.3–0.5	45	0.8	13	40
Fathead	Static	1.3	0.7–2.4	17	0.1	20	41
Fathead	Static	0.8[d]	0.8–0.9	17	0.1	20	41
Fathead	Static	1.3	0.8–2.2	17	0.1	20	36
Fathead	Flow-through	1.7	1.5–7.3	28	0.2	21	33
Fathead	Flow-through	1.0	0.8–1.3	16	0.1	22	39

[a] *Daphnia* tests unaerated; fish static tests aerated.
[b] From measured concentrations.
[c] 48-h EC_{50}
[d] Trimmed Spearman-Karber analysis.

throughout all tests conducted. The National Research Council of Canada [8] presents water solubility data for endosulfan, with values ranging from 60 to 260 μg/L. Triethylene glycol was the solvent-dispersant used for all static endosulfan tests. In addition to regular controls, the static tests had solvent controls run at the same solvent concentration used for the high-endosulfan test concentration. For the static *Daphnia* and fish tests, the endosulfan was added to water in the test containers and mixed thoroughly before animals were added. Samples for chemical analysis of the static tests were taken from the test containers at the beginning of the test. For the endosulfan flow-through tests, a sand column was saturated with technical-grade endosulfan and water flowing through the column dissolved the endosulfan to near saturation, delivering it at a constant rate to the first chamber of the diluter where a 0.5 dilution was used. An average concentration was determined from daily samples.

Ninety-six-hour LC_{50} values were calculated for the fish and 48-h EC_{50} (effect concentration resulting in 50% immobilization) values were obtained for *Daphnia*. The LC_{50} and EC_{50} values were determined using logistic regression methods [9]. One test was analyzed using the Trimmed Spearman-Karber method [10].

RESULTS AND DISCUSSION

Table 1 presents the results obtained during this study. Fathead minnows were sensitive to endosulfan, with LC_{50} values ranging from 1.0 to 1.7 μg/L. Rainbow trout were also very sensitive to endosulfan, with 96-h LC_{50} values as low as 0.3 μg/L. The 48-h EC_{50} values (without food) for the two *Daphnia* tests were 343 and 271 μg/L for total endosulfan. There were small differences between fish static and flow-through values, but they were minor compared to the differences between fish and daphnid sensitivities. Rainbow trout and fathead minnows were much more sensitive to endosulfan than was *D. magna* during acute testing. The 48-h EC_{50} value of 343 μg/L for *D. magna* is 200 to 1,000 times greater than 96-h LC_{50} values for the fish.

These results are similar to those obtained by Schoettger [1], who obtained an unmeasured LC_{50} value of 62 μg/L for *D. magna*, and an LC_{50} of 0.3 μg/L for rainbow trout, a 206-fold difference in toxicity. Macek et al. [3] also showed a 100-fold difference, with an unmeasured LC_{50} of 166 μg/L for *D. magna* and an LC_{50} of 1.5 μg/L for rainbow trout. Sensitivity to endosulfan is apparently different for the fish and daphnids, showing that we can not necessarily extrapolate toxicity or LC_{50} values among groups of organisms; some testing must be conducted on each major group, as proposed by the U.S. EPA [11].

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